

Sampling the Unexplored Regions of Venus

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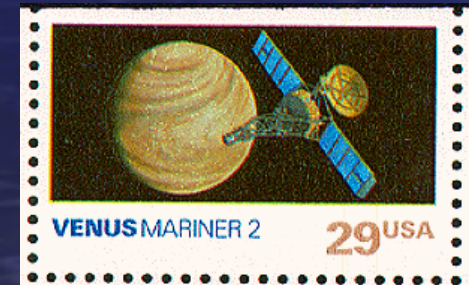
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Why Venus?

Since the confirmation of the high surface temperature by Mariner 10 and the discovery of the global vortex circulation from Mariner 10, Venus has remained a puzzle



- Extreme case of greenhouse effect – what can it inform us about Earth's future climates with increased greenhouse gases?
- Inferred to have had liquid water on its surface based on high D/H ratio in the the atmosphere (below clouds) and even higher above the clouds (Venus Express)
- Did Venus harbor life in its past?
- Indeed, Venus has a habitable zone in the cloud layer
- What is the ultraviolet absorber?

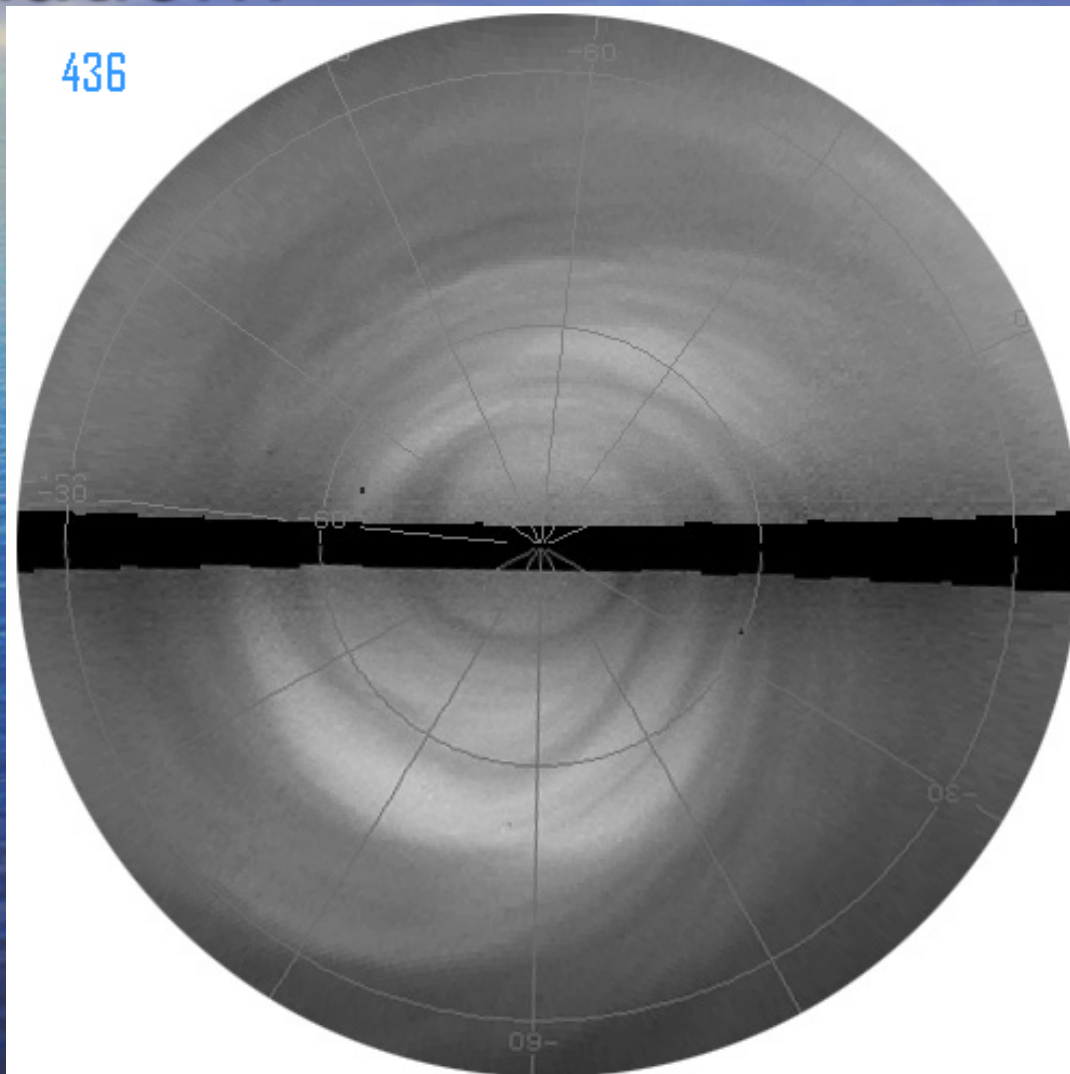


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Venus Surface

- Is Venus geologically active? – Volcanoes, seismic activity?
- How would we detect surface activity above the clouds?
- What caused the re-surfacing in the last few hundred million years?
- Is the spin rate of Venus changing as posed by recent Venus Express data?

What is the connection between the superrotation and the vortex circulation?



How deep is the
vortex circulation?

Polar composites from
Venus Monitoring
Camera on Venus
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Direct Sampling of Venus and its Atmosphere

Venera 4



- Orbiters
 - Magellan and Venus Express (Atmospheric Drag)
- Entry Probes
 - Venera 4-8, Pioneer Venus SP1, SP2, SP3 and LP below 62 km
- Landers
 - Venera 9 – 14, VeGa 1, VeGa 2
- Balloons
 - VeGa 1 and VeGa 2

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Direct Measurements of Venus Atmosphere

- Venera, Pioneer and VeGa probes/landers make measurements below ~ 62 to 64 km
- Above this altitude accelerometers provided pressure/density data from which temperatures were derived
- VeGa balloons measured 53 - 55 km altitude
- Magellan and Venus Express orbiters aerobraking/atmospheric drag data provide density @ $\sim 160 - 170$ km

Why sample the atmosphere above 64 km?

- Cloud top level extends to ~ 75 km in low latitudes
- Haze layers present to ~ 90 km altitude
- UV absorber identity still not confirmed
- Direct ambient three-component wind measurements not available

Science Relevance

- UV absorber is responsible for majority of the solar energy absorbed by Venus
- The contrast features in ultraviolet images of Venus show a variety of morphologies and evolve on short and long time scales
- The cloud motion measurements are somewhat at odds with the cyclostrophic flow inferred from thermal structure data
- No measurements of short period waves/turbulence available
- The inferred angular momentum transport from cloud motions not consistent with theories of superrotation and required angular momentum transport in the meridional direction

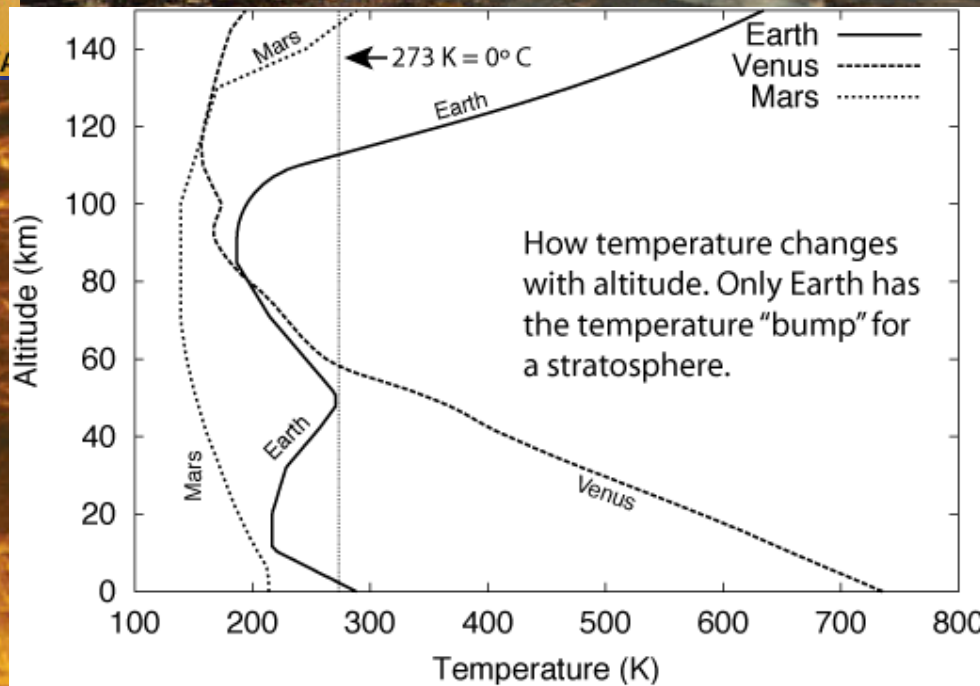
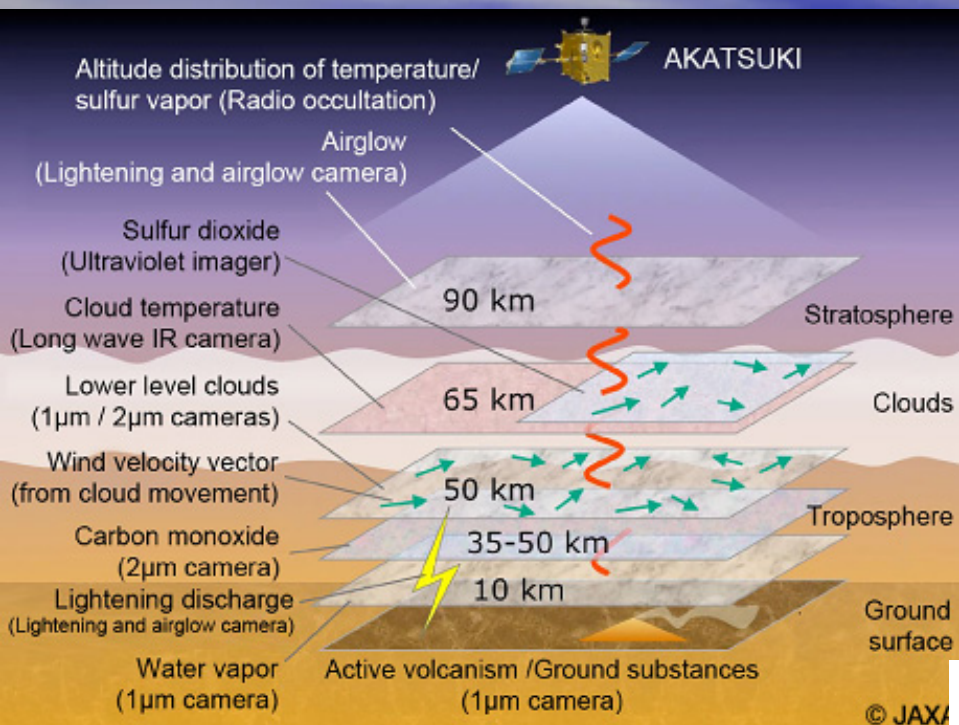
Example of the meridional flow of Venus (atmosphere)

Other atmospheric phenomena of interest in the region at and above the cloud tops

- Transition between super-rotation and day side-night side circulation between 90-110 km
- Air Glow ~ 90-95 km from various photo chemical processes
- Wave braking transferring momentum
- Atmospheric haze layers – what is the source ? sink?

Lower Atmosphere objectives

- The Kinetic Energy and Momentum per unit volume peak at ~ 20 km above surface
- No clouds
- Low static stability
- Is the (horizontal) momentum being transported upwards or downwards?
- Detection of surface activity
- “High” resolution imaging
- Accurate lower atmosphere temperature profile (P/V probes did not obtain measurements below 13 km)

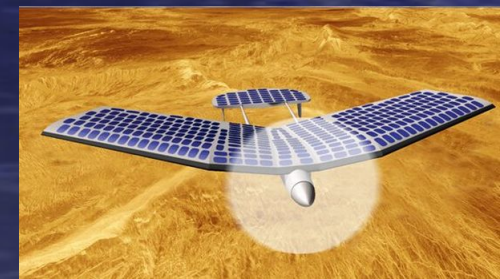


Potential platforms

- Low Altitude Balloons (below 50 km)
 - Phase Change or Metal Bellows
- High Altitude balloons (above 60 km)
 - Often flown on Earth for long term duration flights carrying ~ 1000 kg at 35-25 km
- Mid Level Balloons (52 – 56 km)
 - VeGa 1 and VeGa 2
- Unmanned Aerial Vehicles (UAV)
 - Used commonly in field experiment studies of Earth aerosols and clouds
 - Active and passive flights



VeGa

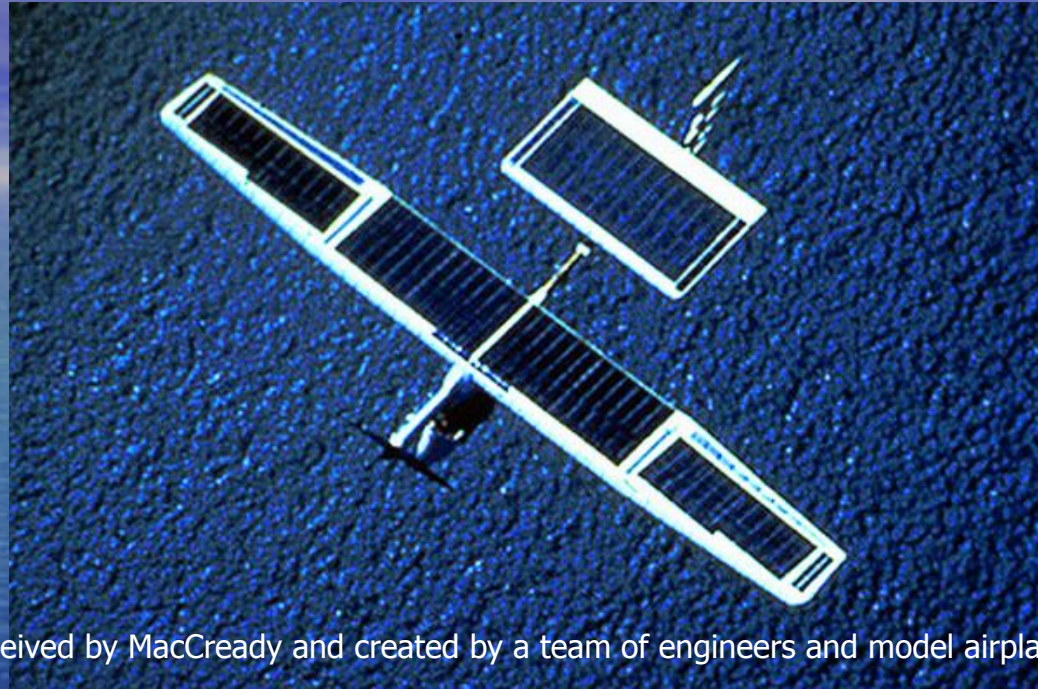


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What measurements are needed?

- Cloud particle size, composition, distinguishing the **uv absorbing** particles
- Cloud particle shape by imaging of captured particles
- Cloud particle composition?
- Vertical and horizontal wind/turbulence
- Pressure, temperature density
- 3-component wind by tracking the balloon motion

Some possibilities that might be considered for Venus?



Solar Challenger - conceived by MacCready and created by a team of engineers and model airplane builders

The Solar Challenger was the first solar powered aircraft capable of long distance flights. The aircraft designed by Paul MacCready's AeroVironment, was an improvement on the Gossamer Penguin which again was a solar powered variant of the human-powered Gossamer Albatross. Solar Challenger featured photovoltaic cells on its wings and stabilizer, without incorporating any reserve batteries. In the year 1981, it successfully completed a 262 km flight from France to England. The Solar Challenger was designed to be more maneuverable and powerful than the Gossamer Penguin and also to withstand turbulence and sustained high altitude flight. It was three times heavier than the Gossamer Penguin, had a shorter wingspan and was more powerful. The Solar Challenger featured 16,128 solar cells powering two 3 HP motors. The motors operated on a common shaft and drove a controllable pitch propeller.

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Concept for a Long-lived UAV at Venus

May 2012

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Northrop Grumman Aerospace Systems

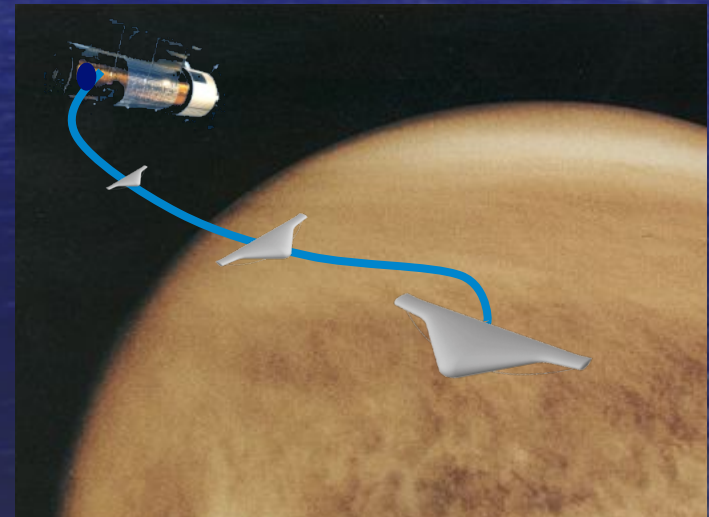
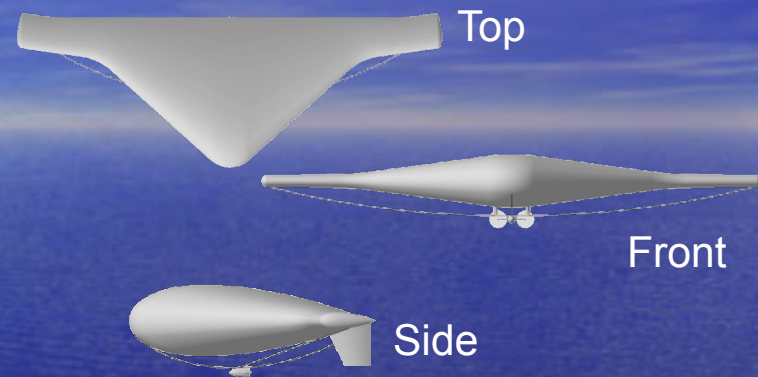


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Introduction to the Concept

- Semi-buoyant unmanned aerial vehicle
 - 5-50% buoyant at cruising altitudes
 - Sinks to altitude of 100% buoyancy and floats when propellers are off
- Strawman payload is balloon payload from Venus Climate Mission
- Propellers provide altitude, latitude, and longitude mobility
 - Flight path is controllable (but not in real time)
 - Ability to survey large areas and/or focus on regions of interest
- Power source is solar panels and batteries
- Supported by orbiting satellite
 - Orbiter delivers UAV to Venus
 - Orbiter serves as data and communications relay with Earth
 - UAV + Orbiter is a good candidate for a Discovery mission
- Entry into Venus atmosphere without an aeroshell
 - UAV inflates in space
 - Large surface area produces benign heating loads during entry
 - Benign entry enables continuous data collection during descent



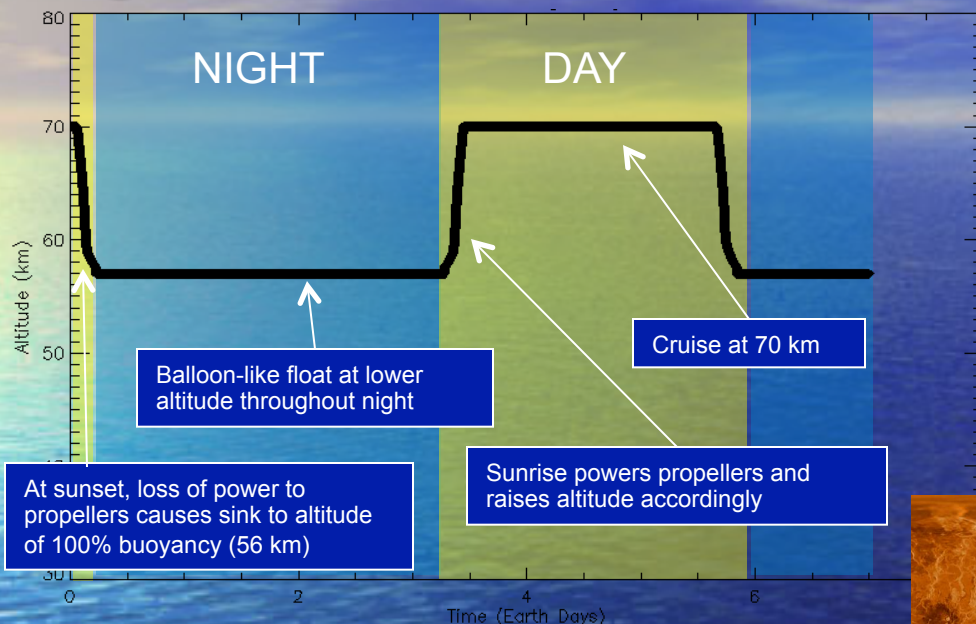
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Mission and Operations Capabilities with a UAV

- Lifetime of multiple months or greater
 - Limited by atmospheric corrosion of vehicle exterior and solar panels
- Flight paths can be directed and focus on regions of interest
 - Altitude range of 55-70 km includes Venus' s “habitable zone”
 - Latitude range of at least $\pm 30^\circ$, depending on vehicle design
- A key design trade is a day-only vehicle vs a day-and-night vehicle

	Day-only	Day-and-Night
Power source	Solar panels	Solar panels and battery
Instrument operation	Continuous	Very limited at night
Flight path	Very limited; propellers primarily used to counteract the wind	Drift with winds; propellers used to direct flight to areas of interest

Sample 1-Day Trajectory of Day-Night Vehicle



Altitude

Fully controllable during the day

Altered via propelled speed

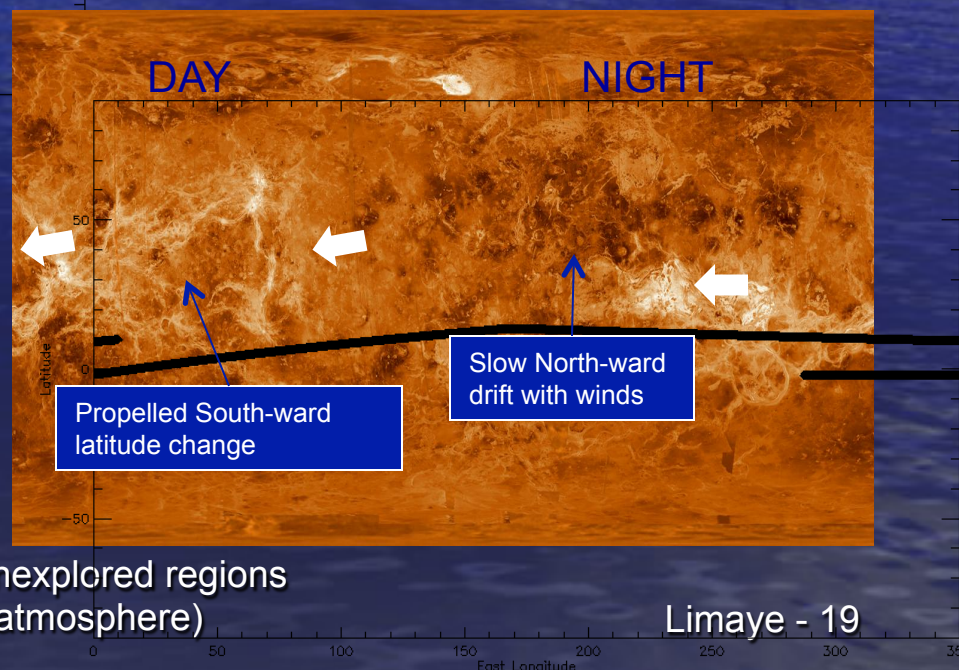
Raised / lowered at will in the 55-70 km range

Latitude

Fully controllable during the day

Altered via propelled direction

Maneuvered at will between $> \pm 30^\circ$



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Summary of Key Advantages and Challenges





Advantages

- Similar instrument capabilities as a balloon mission
- Lifetime of months to a year
- Directed flight with capabilities for global survey and localized monitoring
- Large range of accessible altitudes, latitudes, longitudes
- Data collection throughout entry from very high altitudes
- No aeroshell maximizes mass available to science mission

Technical Challenges

- Sufficient, rechargeable battery power to survive ~70 hr nights
- Protection of solar panels in Venus atmosphere
- Packaging for transfer to Venus and on-orbit deployment sequence

Heritage

Item	Heritage	Reference
Buoyant structures on Venus	Significant development of balloon materials etc	JPL: Prototype balloon exists 
Construction and operation of semibuoyant vehicles	Terrestrial blimps have similar ambient flight environment	Northrop Grumman: LEMV semibuoyant vehicle under construction 
Use of UAVs for automated science observation	Terrestrial robotic, air-based Earth Science observations	Northrop Grumman: GlobalHawk 
Autonomous navigation and hazard avoidance	Frequently used in planetary science missions	Northrop Grumman: LCROSS autonomously navigated to lunar impact 

Future Venus Mission Opportunities

- ESA Cosmic Vision ~ 2013-2014
- NASA Discovery (NET 2015)
- NASA New Frontiers – 4 (NET 2016)
- Other agencies?

International coordination and collaborations are key to future exploration of Venus!

International Venus Exploration Focus Group – VEXAG (
www.lpi.usra.edu/vexag)

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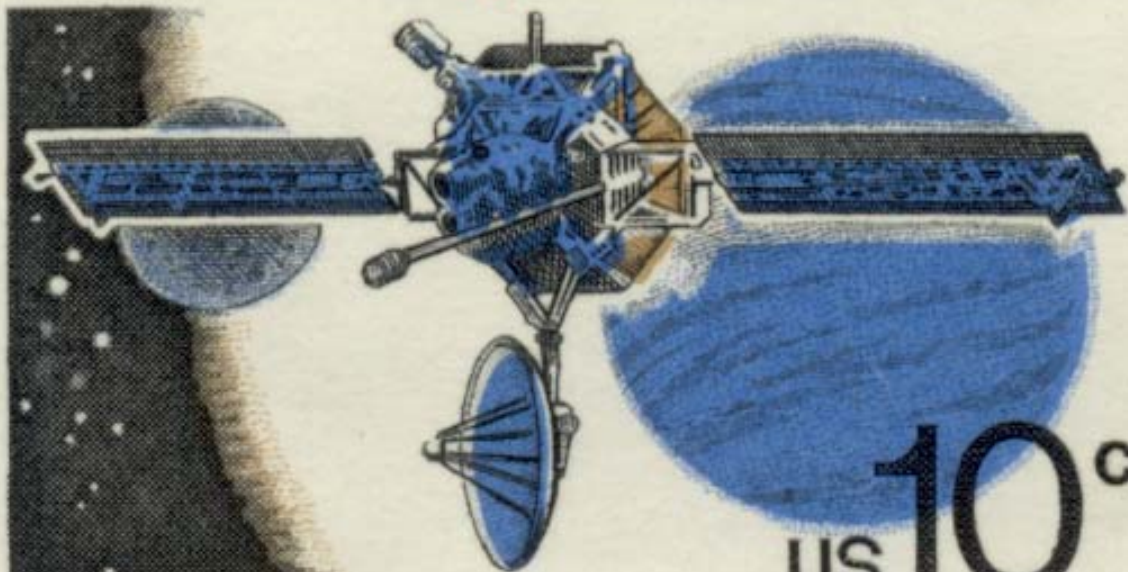


Sunseeker by Eric Raymond

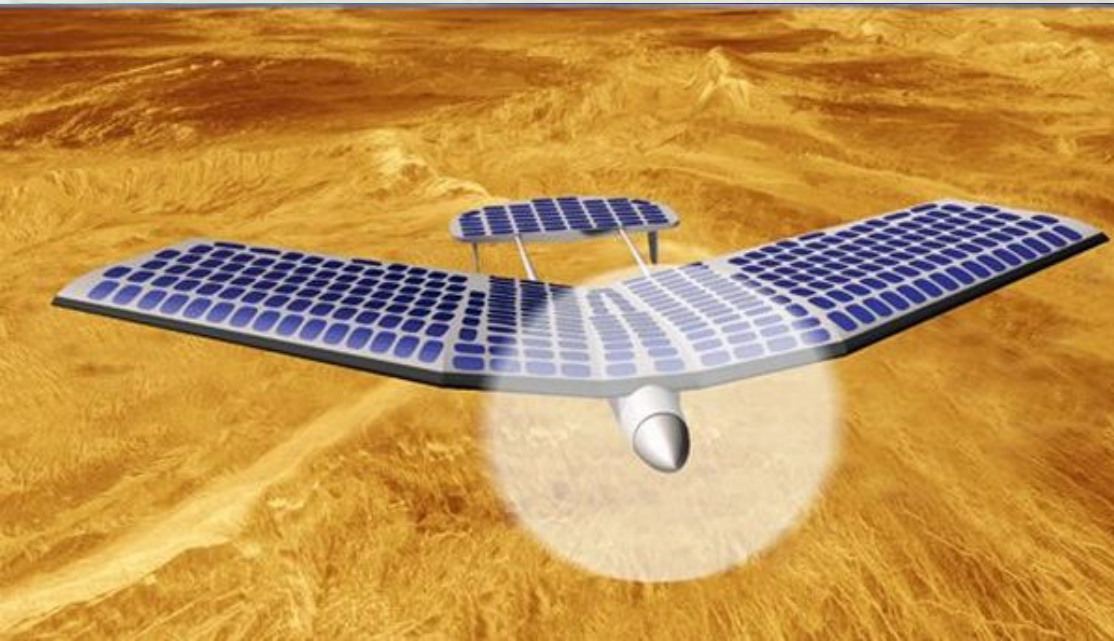
Based on construction technology, the Sunseeker II is the only manned solar airplane in the world and has stayed for more time in the air than all other manned solar planes combined. This hybrid aircraft uses battery power to take off and uses solar power to maintain flight. The design integrates solar cells into the actual wing structure which also features lithium polymer batteries. A unique teetering propeller considerably reduces vibration. Under direct sunlight the Sunseeker II flies at 40 mph, undoubtedly a slow speed by aircraft standards, making it susceptible to be hit by birds.

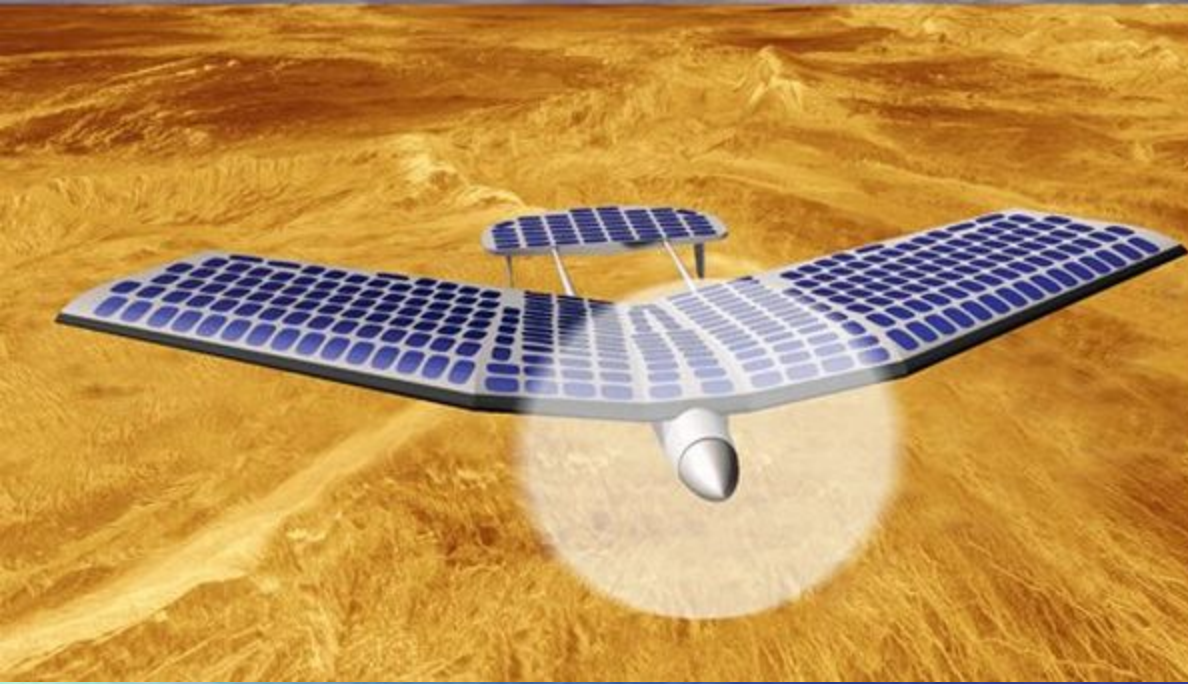
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MARINER 10 ★ VENUS/MERCURY



US 10^c





Venus The craft would have to be capable of sustained flight at or above the wind speed, about 95 m/sec at the cloud-top level, 65 to 75 km above the surface

The intense heat and air pressure on the surface of planet Venus makes lander missions almost impossible. Instead, a mission flying in the atmosphere of the planet and closer to the surface would be particularly helpful for collection of a detailed amount of data. In year 2007, NASA formed a Science and Technology Definition Team (STDT) to study the concept of a flagship mission to Venus. According to Dr. Geoffrey Landis from NASA's Glenn Research Center, a small solar powered aircraft could fly continuously on the atmosphere of Venus and gather information on the planet's surface and atmosphere with the ability to maneuver almost everywhere. Landis and his team, who have been studying and working on this concept since the year 2000, have presented their findings for Venus to NASA's STDT. The airplane which would have to fold up to fit inside a small aeroshell would deploy from the shell after landing on the planet, unfold and glide through the atmosphere. Since the solar cells would cover the entire surface, the airplane would be powered by solar energy, not needing any fuel. The design drawn by the team features a wingspan of 9m and a length just under 7m. However a problem for the solar airplane to fly on Venus would be the wind and to keep it flying under the sun, the airplane must be designed to fly faster than the wind. It must also be capable of sustained flight at or above the wind speed. The aircraft can glide down to lower altitudes and then climb back, probing the cloud layers in between. Although Landis and his team have designed this solar powered aircraft basically to study the atmosphere of Venus, they are also considering using the aircraft for radar mission.

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